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RADIUM

A MONTHLY JOURNAL DEVOTED TO THE CHEMISTRY, PHYSICS AND THERAPEUTICS OF RADIUM AND RADIO-ACTIVE SUBSTANCES.

Edited and Published by Charles H. Viol, Ph. D., and William H. Cameron, M. D. with the assistance of collaborators working in the fields of Radiochemistry, Radioactivity and Radiumtherapy.

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OCCUPATIONAL INJURIES DUE TO RADIUM

REPORT OF CASES[1]

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ALBANY, N. Y.

During the past two years, the Cancer Commission of Harvard University has been engaged in obtaining data concerning the therapeutic value of radium. Owing to the great variety in type of lesions to be treated and in their distribution, the methods of application have been varied, chiefly as to differences in filtration and protection. This has necessitated in the application the frequent manipulation of highly radio-active tubes and applicators.[2]

Rutherford[3] says:

"Walkhoff first observed that radium rays produce burns of much the same character as those caused by Roentgen rays. Experiments in this direction have been made by Giesel, Curie and Becquerel and others with very similar results. There is at first a painful irritation, then inflammation sets in, which lasts from ten to twenty days. This effect is produced by all preparations of radium, and appears to be due mainly to the alpha and beta rays. Care has to be taken in handling radium on account of the painful inflammation set up by the rays. If a finger is held for some minutes at the base of a capsule containing a radium preparation, the skin becomes inflamed for about fifteen days and then peels off. The painful feeling does not disappear for two months."

Although these rather *acute* reactions due to radium are apparently well known to *physicists* working with radioactive substances, and considerable experimental work has been done on animals by biologists,

1. Jour. Am. Med. Assn., LXVI, 1-6, Jan. 1, 1916.
2. Ordway, Thomas: The Use of Radium in Cancer and Allied Conditions at the Huntington Hospital. Boston Med. and Surg. Jour., Nov. 19, 1914. Abstract Radium, Vol. 4, p. 74, Jan., 1914.
3. Rutherford, Ernest: Radioactive Substances and Their Radiations, New York, G. P. Futnam's Sons, 1913, p. 327.

very little attention has been paid to the more chronic changes. The purpose of this paper is to record a detailed description of symptoms and signs from the *clinical* point of view, and to emphasize the importance of these as occupational injuries, so that more serious effects may not result in those engaged in the application of radium as a therapeutic procedure.

Personal observation in London and Vienna and in Germany while I was investigating the status of clinical work with radium had led me to note the possibilities of discomfort and injury from contact with radioactive substances.

In London at the Radium Institute the plan was adopted of rotation in service each month for the nurses handling the applicators. Attention had been called to the effects on the fingers of those handling the radium by sensory disturbance in the form of pain and anesthesia, first noticed by the difficulty experienced in preparing eggs at the table according to the English custom. This may seen a trivial instance, but it well illustrates a peculiar sensitiveness to heat and the difficulty of delicate manipulation with the affected fingers.

On the other hand, severe injury was observed in Vienna in the case of one who had handled large quantities of radium. The thumb, forefinger and middle finger of the left hand showed severe lesions, particularly in the form of atrophy and intractable ulceration.

In Paris at the Laboratoire biologique du radium, particular inquiry was made as to the effect of radium on the hands, and it is interesting to note that one of the attendants who had been making almost daily surface applications for over two years had up to that time experienced no injurious effects whatever. This is probably due in part to the type of applicators used in this clinic.

From this it will be seen that injurious local effects were anticipated so that the changes to be described were not acquired unwittingly but in spite of caution. The increasing use of large quantities of radium warrants a detailed description and record of these changes, not only because of the annoyance and discomfort caused, but also as a warning from analogy to the Roentgen ray of more serious late effects, such as atrophy, intractable ulceration and even cancer. Already in certain instances there has been caused not only great annoyance from discomfort but actual impairment in manual dexterity in performing delicate manipulations because of persistent local anesthetic effects.

Throughout the first year of the radium work at the Huntington Hospital, a considerable proportion of the applications were made by the physician in charge. As a result of manipulation due to the clinical applications of radium in the variety of cases referred to above, a few weeks after beginning there was noticed slight though gradually increasing sensory disturbance in the finger tips, particularly on the ulnar side of the first phalanx of the thumb and the radial side of the terminal phalanges of the index and middle fingers of each hand.

These symptoms occurred very insidiously, and consisted of blunting of sensibility of the finger tips, paresthesia, such as increased sensitiveness to heat and pressure, amounting at times to actual pain, and anesthesia of varying degrees.

The subjective disturbances were out of all proportion to the objective findings, which included flattening of the natural ridges on the affected fingers with consequent changes in the characteristic markings of the finger prints, thickening of the horny layer of the epidermis

with scaling, failure of the tips of the fingers to resume their normal shape after pressure, a sort of pitting and upgrowth of the cuticle at the base of and underneath the nails, which were easily cracked, extremely brittle, and tended to stand off from the fleshy part of the fingers.

Each assistant and nurse before engaging in the clinical application of radium was warned of the annoying and possibly dangerous effects, and told not to handle the active tubes of emanation with the fingers but to make use of forceps. In spite of this, a certain amount of handling was unavoidable in changing the radium tubes for suitable filtration and protection in the different cases.

Nurses and assistants, and also members of the commission have been asked to describe carefully and independently the subjective and objective changes produced. The onset, variety and annoyance of the effects may be best understood and appreciated by the individual descriptions to be cited, for the most part in the sequence of their occurrence.

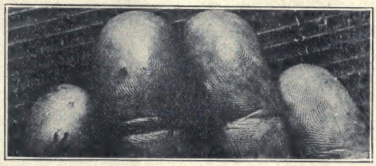

Fig. 1 (Case 7).—Photograph showing the flattening of the ridges on the tips of the index and middle fingers compared with the ring and little fingers, left hand.

Case 1. (C. O. 15.20).—A physician began making routine applications of radium during the early part of November, 1913. These continued in increasing numbers until the latter part of January, 1914. Since that time, applications have been made only in special cases.

After a few weeks the tips of the thumbs, particularly toward the ulnar side, and the fore and middle fingers, especially toward the radial side, gradually became numb and felt unnatural from the blunting of sensibility. They were very tender on pressure so that buttoning small buttons was not only difficult because of the anesthesia but also painful. Hyperesthesia was also noted in a markedly increased sensitiveness to heat. There was paresthesia in the form of a peculiar unnatural feeling of the finger tips and awkwardness in using the fingers for delicate manipulation. Because of the anesthesia, small objects were frequently dropped, and difficulty was noted in taking pulses with the affected finger tips, which are those commonly used. These subjective symptoms have been very pronounced, persistent and out of all proportion to the objective findings.

The affected portions of the fingers described above became smooth and shiny, and the ridges giving the characteristic finger prints became less marked and almost obliterated (Fig. 1 and 2). Later the epidermis was thickened, dry and parchmentlike, and on pressure the pad of the finger tip remained indented for some seconds instead of immediately resuming its rounded form (Fig. 3).

The thickened horny layer became wrinkled and cracked, and scales of varying size repeatedly desquamated. The nails stood off from the fleshy part of the affected fingers, and there was a marked tendency for the upgrowth of the tissue beneath the nail (Fig. 4 and 5).

At the present time, although the patient has actually handled the radium for clinical application only occasionally for almost a year, the pain, tenderness and sensitiveness to heat and the objective signs have largely disappeared; notwithstanding this interval, the dryness, parchmentlike feeling, partial anesthesia and slight tenderness of the affected finger tips persist.

Case 2 (C. O. 15.21).—A nurse began making routine applications of radium in December, 1913, and continued this until the last of February, 1914. After that time occasional applications were made with an interval of three months on vacation. "Two weeks after first handling the radium tubes, dryness of the skin was noted. A little later the flesh on the finger tips of both hands, especially the thumbs and forefingers, looked yellow and was easily indented on pressure. In about a month the skin over the finger tips began to crack and peel, and the dryness of the skin extended down the fingers to the palms of the hands. The flesh grew more rapidly than normally at the base of and below the free edge of the nails, which became very brittle. Numbness developed in the finger tips of both hands, awkwardness in picking up articles, pain on buttoning clothing, sensitiveness to heat and later hot throbbing sensations extending the entire length of the fingers on handling radium. At present there is no tenderness, but marked paresthesia and slight anesthesia, slight peeling, dryness and marked numbness of the tip of the thumb, index and middle finger of each hand. Great annoyance is caused and difficulty in delicate manipulation."

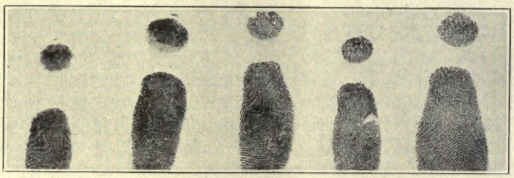

Fig. 2 (Case 4).—Finger prints of fingers of the left hand. Note that the characteristic ridges are less marked and show more breaks on the thumb, index and middle fingers, particularly on the extreme tips; left hand; from left to right: little finger, ring finger, middle finger, index finger and thumb.

Case 3 (C. O. 15.22).—A nurse began making routine clinical applications of radium in February, 1914, and continued until June, 1914.

"After a few weeks the tips of the fingers became yellowishwhite, gradually growing whiter until the fingers looked as if they had been burnt. The skin about and under the nails hardened and grew thicker. The fine lines on the finger tips began slowly to disappear, leaving the tips tight, white and swollen. The finger tips remained white, and minute cracks appeared. Then from the whole tip of the fingers the skin peeled off, leaving the ends smooth, pink and shiny (Fig. 6).

"The tips of the middle finger and thumb of the left hand again became swollen and hard; the thumb appeared yellow as if calloused; the skin is dry and cracked and there is a spot on the thumb 1 by 2 cm. that is red and smooth where the upper layer of skin is cracked and peeled off.

"The left forefinger is swollen, hard and yellowish brown with minute cracks as if the skin were too tight; the fingers are not wholly straight, but curved a bit toward the palm. The nails seem to stand

out from the fingers (Fig. 4). The cuticle is dry and white, cracked in some places and inclined to grow around the nail. The finger tips dent on pressure.

"Subjectively it is noted that the fingers were sensitive to pressure especially on the nail. They gradually became stiff and were tender on bending. Definite pulsation was felt about a month after first using the radium. The fingers were very hot and felt much as a mildly septic finger feels; they gradually became oversensitive to heat, and the sense of touch was not so sure. Articles would drop from the fingers.

Fig. 3 (Case 1).—Photograph showing the tip of the thumb remaining indented after pressure indicating the hardening and "empty" feeling of this finger; a late effect; moderately anesthetic.

"This has been persistent up to the present time, and it is hard to pick up pins or button anything. Pressure on the nail and on the very tip of the finger is painful. The fingers feel very hard, stiff and awkward. It is difficult to tie and loosen hard knots. The hand is dry and rough, and feels big."

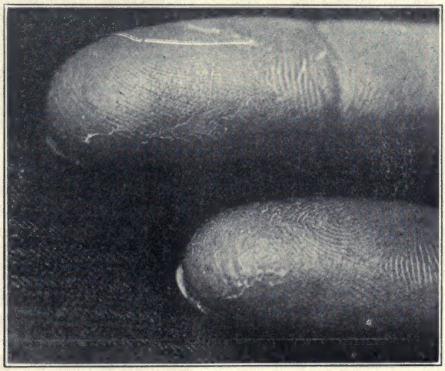

Fig. 4 (Case 3).—Photograph showing the flattening of the ridges of the tips of the index and middle fingers of the left hand. Note how the free ends of the nails stand away from the fleshy part of the finger tip; also note on the forefinger the upgrowth of the skin beneath the nail.

Case 4 (C. O. 15.23).—An assistant, medical student, began making routine clinical applications of radium, June 3, 1914. "The work consisted in transferring glass capillaries of emanation from one steel jacket to another, or to flat applicators (Fig. 7) in fixing silver sheaths over the steel, in arranging a number of steel tubes between pieces of lead,

paper and gauze and then wrapping all together in rubber sheeting and adhesive. Tubes of emanation were also placed in various special applicators. In unscrewing the tubes they were held in dressing forceps by the left hand, and the points and eyes were held by the right hand occasionally between the thumb and forefinger, but almost always straight half length hemostats. The applicators were held in the left hand and fastened with adhesive by the right hand. Glass capillaries have never been picked up or held by the fingers, and only rarely in the early part of the work were the steel tubes so held and then for not more than a few seconds. The number of applications per day has varied from five to sixteen, average ten. This indicates approximately the number of times a day that the tubes were handled or changed.

"During the first three weeks there was no noticeable effect. Then gradually the tips of the thumbs and index fingers assumed a smooth shiny appearance with flattening of the ridges (Fig. 1 and 2). This became noticeable at the end of the fourth week. Up to this time there was no unusual sensation. During the fifth week a very thin layer of epidermis loosened and peeled off the tips of the thumb and index fingers from the nail to half way to the second phalanx; this scaling took a week, during which the finger tips affected became somewhat swollen, and there was a sense of fullness in them. They were warmer to touch than the other fingers of either hand. There was slight sensitiveness to pressure and a tendency to drop small objects, such as pins, if picked up in the usual manner. During the sixth and seventh weeks the fullness and discomfort disappeared. In the eighth week the swelling increased and the skin became tense; the sense of fullness returned, and pain was experienced on touching a small object, such as the head of a pin. There was also some difficulty in picking up small articles and holding them, especially if not directly thinking of them. After the eighth week of making radium applications a vacation of two weeks was taken; during this time, in which no radium was handled, the outer layer of skin on the affected finger tips again became white, hard and peeled off, leaving the fingers much more sensitive to pressure, either gradual or sudden, and to heat. Indeed, severe pain was felt when taking up a cup of hot coffee, a heated test tube or on washing the hands in water of such a temperature as was not at all painful to the unaffected parts of the skin.

"Similar process of swelling of the finger tips, hardening of the superficial layers, cracking and peeling was repeated in the thirteenth, fifteenth and seventeenth weeks. Each time during and immediately following the peeling there was marked tenderness and acute pain on striking or pinching any object; occasionally a throbbing sensation, more marked if the arms were hanging down, was felt in the affected fingers. The tenderness was so severe that it was difficult to button small buttons, or to tie or untie knots, such as shoe strings and necktie; in one instance a room mate's assistance was required in undoing a tightly drawn necktie. At present the skin of the tips of both thumbs and index fingers and small areas of the left middle and ring fingers is smooth and shiny, the ridges are flattened or absent, and the surface is cracked in appearance. When pressed on the flesh of these finger tips remains indented for an appreciable time. There is no apparent difference in vascularity as judged by their color.

"The index finger and thumb of the left hand, which is most affected, are distinctly tapering in contrast to the flat blunt tips of the other

fingers and to their own condition before June 1. On fully extending these two fingers and to a less extent the index finger of the right hand, there is a marked pulling sensation at the junction of the flesh and the nail. The finger tips are at the present time only moderately tender."

Case 5 (C. O. 15.24).—Assistant, medical student, began making clinical applications of radium, July 4, 1914. "First noticed slight tenderness in the tips of left thumb and index finger. This gradually increased to pain on touching objects. Otherwise there was no abnormal sensation. About Aug. 8, 1914, felt in the finger tips a very distinct pulsation which made it impossible to take the pulse for blood pressure estimation in the usual way. About this time a slight darkening of the color and numbness was noticed. This involved also the tip of the middle finger of the left hand. The tenderness disappeared, but the numbness increased until there was such marked anesthesia that it was impossible to button the shirt without looking because the button-hole could not be felt with the forefinger or the button with the thumb. The finger tips when pressed on would retain the impression much longer

Fig. 5 (Case 1).—Photograph showing the free edge of the nails standing away from the fleshy part of the finger tips and also indicating the upgrowth of horny skin beneath the nails. Compare index and middle with ring finger.

than usual. About a week later a small white spot appeared on the tips and became almost 1 cm. in diameter. This was picked off out of curiosity; it resembled a callus of the palms. The skin beneath was smooth, bright red to pinkish in color, dry and extremely tender. Three areas similar to this appeared. One cracked open, but there was no tendency to bleed. The tenderness was so great that it was necessary to bandage the fingers for a week, when the cracked area healed. On the three fingers of the right hand the superficial layer of skin peeled from the tip to the middle phalanx. At present date the fingers appear normal except for smooth, glossy appearance and a tingling sensation which seems to spread over the whole finger tip when a small object such as the head of a pin is touched."

Case 6 (C. O. 15.25).—Assistant, medical student, made no routine clinical applications of radium, but on one occasion brought the day's supply of radium emanation from the physical laboratory to the hospital and thoughtlessly put the active tube in his pocket. "On July 28, 1914, I carried a tube containing 32 millicuries of radium emanation in the left pocket of my trousers for about one hour. On Aug. 4, 1914, I

noticed an irregularly oval red spot on the anterolateral aspect of my left thigh. It was about 2 cm. long and 1 cm. wide. At this time there was no tenderness. The red spot gradually became tender, at first only to marked pressure and later to a slight touch. The skin in the center of this spot became yellowish, and by Aug. 12, 1914, there was a yellowish spot surrounded by a red border which faded into the surrounding normal skin.

"At this time the spot was very tender and felt warm. About August 15 the yellowish skin had scaled off, leaving a bright glistening yellowish-red area (Fig. 8) which soon became covered with a crust. This was frequently rubbed off and reformed, each time being smaller, until September 5, when the crust disappeared, leaving a smooth somewhat glistening area a little more red than the adjacent skin and surrounded by a margin of slight pigmentation. September 28 the redness is gradually fading. December 16 the area is now smooth, white and there has been no tendency for the hair to grow out again."

Case 7 (C. O. 15.26).—A physicist reports: "My first finger burns from the radioactive substances occurred six or seven years ago, and I do not remember their symptoms in detail. They came from handling large quantities of emanation—from 200 to 250 millicuries.

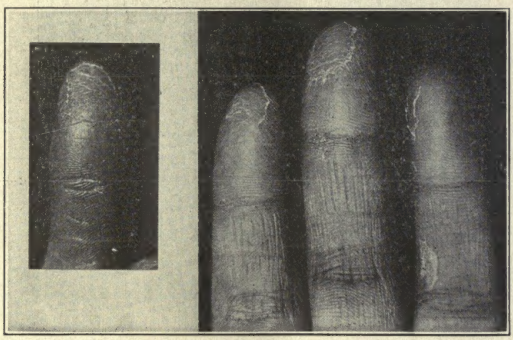

Fig. 6 (Case 3).—Photograph of thumb, index, middle and ring fingers of left hand showing the scaling of the thickened superficial layer of the skin on the radial side of the terminal phalanges and also a similar small area on the second phalanyx of the ring finger.

"Since then six of my fingers have been burned six or seven times, severely enough for the skin to peel off. I have noticed the following symptoms in varying degrees of intensity: sensitiveness to pressure and heat lasting several days, sometimes so much that it becomes impossible to button buttons and hold warm eggs. Occasionally there has been continuous dull pain without pressure or heat. Each finger has been slightly red with a small yellowish spot at the point of the most severe burn. After four or five days the pain and sensitiveness passed away, and the fingers gradually become calloused. After several weeks the skin peeled off over a considerable area, leaving fresh skin that was quite sensitive for a few days. The lines that previously disappeared returned, and the finger tips were smaller than normal for a time, but gradually filled out. In no case has a finger ulcerated.

"There is sometimes a desire to hold the hands closed tighter than

they usually rest. On the whole my fingers appear to be less sensitive to touch, etc., than they used to be."

Case 8 (C. O. 15.27).—A physicist devotes a part of his time in the laboratory daily to pumping the radium emanation into capillary glass tubes, and sealing these into lengths suitable for applicators. During this time the activity is comparatively slight, and they are retained in the laboratory three hours until the maximum intensity develops, when the measurement of the activity is made. "I so frequently burn the tips of my fingers while blowing glass that I was never quite certain, during the early stages of a radium burn, whether the pain was caused by a heat burn or a radium burn. The two sensations are, however, dissimilar. The pain of a radium burn is not at the surface; it is probably better described as 'soreness.' The nearest approach to it in heat burns are the burns caused by holding a glass tube which is just hot enough to cause a burn after four or five minutes. Radium burns, like heat burns, are sensitive to heat. I find it difficult to hold glass in the flame for glass blowing. Radium burns are more painful in the morning. I first notice them while dressing. The explanation of this seems to be that they are relieved by massage, manipulation of the flesh removing the soreness. As the burn progresses, the skin becomes hard and horny. The surface layers later peel off. It has seemed to me that as the burns are getting well, the burned tissue is not as firm as normal tissue; it feels as if there was a hollow space in the end of the finger. Up to March 26, 1914, I have had seven burns."

Case 9 (C. O. 15.28).—An assistant, medical student, reports: "On Sept. 1, 1914, I first began to use radium, but it was not until October 1 that I began to apply it daily in the routine work of the hospital. From then on to the present time I have done part of the outpatient work and some of the work on the house cases. The applicators used were of all sorts, steel tubes, silver tubes and flat applicators. Knowing the effects on others employed in radium application, I have been extremely careful throughout not to expose my fingers unduly, using forceps whenever possible. About December 1 I first began to notice some tenderness in the tips of the index and middle fingers and thumb of the left hand, but the index finger was more tender than the others (I am left handed). A short while afterward the affected finger tips began to feel numb, and sensation was deadened as if a finger cot were drawn over each. The finger tips appeared red, when pressured they felt pulpy, and when the pressure was removed the skin remained depressed like parchment.

"During the last week of December I accidentally seared the tip of my left index finger with a match. The burn was slight and under ordinary circumstances would have healed in a few days. Contrariwise, in two or three days it began to peel, and by January 1 the whole palmar surface of the terminal digit and on the sides toward the nail had peeled, leaving a smooth reddened surface which was exquisitely tender. It was especially sensitive to heat, warm water almost causing me to cry out in pain.

"Three days ago the left thumb showed a tiny break in the skin on the palmar surface toward the tip of the index finger. Within two days it had peeled off entirely, as did the index finger, and the symptoms were the same.

"I have had some relief by applications of 'white wash' left on over night.

"The fingers of the right hand show slight smoothing out of the

papillae, especially on the thumb and index finger, but no redness or marked tenderness. The sensation of touch is numbed, but not to such a marked degree as in the left fingers.

"It is difficult to state just where to look for the errors in technic to bring about the above burns. At first I thought it might be caused by brief exposures when screwing the eyes into small unscreened steel tubes. The more likely cause it seems is in putting up special applicators or flat applicators where it is almost necessary, under our present technic,

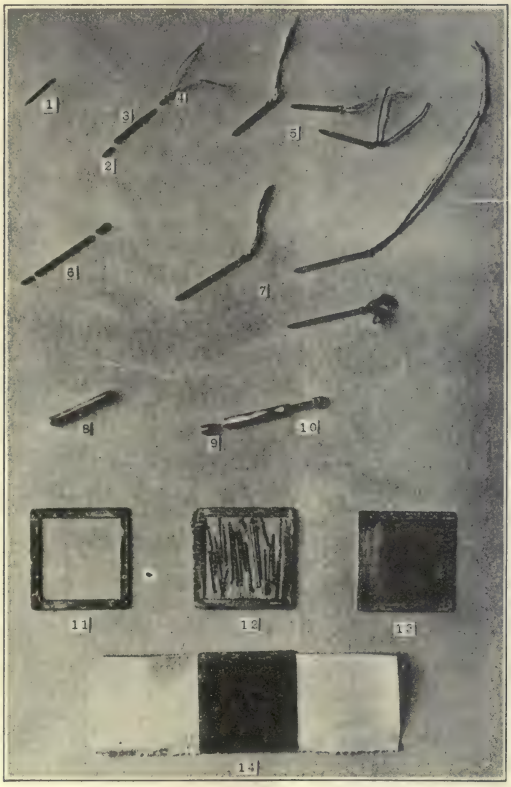

Fig. 7.—Applicators utilized in routine radium treatment (two-thirds natural size): 1, small capillary glass tube containing emanation; 3, thin steel tube to protect 1 from breaking; it is closed by screw ends, 2 and 4; 2 is pointed and 4 has a small eye; 5, same as 3, showing ends closed; one end is tagged with a piece of colored thread for identification as to the measurement of its activity; 5, short steel tubes with pointed ends containing emanation tubes similar to 1; 6 and 7, similar to 5, but twice as long; 8, silver sheath for 7, walls 1 mm. in thickness for filtration; 9 and 10, large rounded ends to prevent perforation of rubber covering; 11, frame of surface applicator; 12, surface applicator containing small emanation tubes, 1, which have become too weak to use in single containers; the small tubes are placed on adhesive plaster, which is applied to the steel frame, 11; 13, square of metal which may be applied to 12 by adhesive, as indicated in 14, for protection or filtration.

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to run one's fingers over the tubes or to hold them while a piece of adhesive is being put in place."

COMMENT

In these individual descriptions of the symptoms and signs, the similarity is striking. In certain instances, however, Cases 5, 6, 7 and 8, the injurious effects were due for the most part to acute reactions. In Cases 3 and 4 the changes were chronic with super-added acute, while in Cases 1 and 2 there were no acute burns, but the changes were the slow and insidious effect of repeated exposures. Indeed, in Case 1 there seems at the present time to be a peculiar susceptibility to slight exposure, even after a long interval in which radium has been but rarely handled.

Various general symptoms, such as headache, malaise, weakness, undue fatigue, unusual need of sleep, increased excitability, fretfulness, irritability, disorders of menstruation, attacks of dizziness, etc., have been said by Gudzent and Halberstaedter[4] to be caused by repeated and long-continued exposure to radioactive substances. Such symptoms are, however, common in many persons at times, and as they cannot be accurately and objectively recorded, there is doubt if they can be definitely proved to be due to exposure to radium. They may be due to close confinement, tiring routine and lack of outdoor exercise and other causes. The exposures of some of the cases reported were doubtless large; some were assistants in "fabriks" for manufacture of radium apparatus, and some had been engaged for years during the entire day in work with radioactive substances. It is probable, therefore, that certain general symptoms did occur as a result of this exposure. These symptoms, however, will not be considered in this paper.

BLOOD EXAMINATIONS

Case	Date	Hemoglobin, Per Cent.	Red Blood Cells	White Blood Cells	Polymorphonuclears	Lymphocytes	Large Mononuclears	Eosinophils	Mast Cells
1	8/25/14	100	5,300,000	6,800	46.3	50.7	2.0	0.8	0.2
	9/ 3/14	94	4,708,000	6,900	49.5	47.2	1.0	2.0	0.2
2	1/ 4/15	99	4,464,000	7,400	55.5	34.5	7.0	2.5	0.5
3	8/21/14	99	4,480,000	7,200	60.2	35.7	2.8	0.5	0.8
4	8/18/14	100	5,400,000	9,000	73.6	23.6	2.2	0.2	0.4
	1/ 6/15	100	5,108,000	7,000	61.	30.5	7.75	0.25	0.50
5	1/15/15	...	5,792,000	8,000	64.5	26.	6.0	1.0	2.5
6	9/ 2/14	100	4,900,000	5,500	53.3	43.8	1.4	0.7	0.8
7	8/21/14	100	5,100,000	6,600	49.8	45.7	3.8	0.5	0.2
8	8/25/14	100	5,600,000	6,000	59.2	33.7	2.6	4.2	0.3
	8/31/14	100	5,400,000	7,800	52.4	39.3	4.8	3.0	0.5
9	2/13/14	...	.....	8,000	51.	45.	3.	1.	0.
Control A	8/27/14	100	5,500,000	8,400	67.6	28.5	2.9	1.0	0.
Control B	1/ 7/15	72	4,112,000	8,800	67.5	26.	6.0	0.25	0.25

Changes in the blood of radium workers were observed by Gudzent and Halberstaedter.[4] Most striking was the relative and absolute in-

4. Gudzent and Halberstaedter: Deutsch. med. Wchnschr., March 26, 1914, p. 633. Abstract, Radium, Vol. 3, p. 27, May, 1914.

crease in lymphocytes: from 36 to 63 per cent.; average of ten cases, 46.4 per cent.; a relative and absolute decrease in neutrophils, average 50.3 per cent. There was little change in red blood corpuscles, slight diminution in white cells and the hemoglobin was lowered in only two cases, 70 and 71 per cent., respectively.

The blood examinations in the cases detailed above are recorded in the accompanying table.

Although the changes are not striking in all instances, in Cases 1 and 7 the findings correspond with those mentioned above. In the other cases the changes are less marked, though suggestive. Case 4 (in which the assistant had just returned from a vacation away from radium exposure) and Control Case A under similar confining laboratory conditions, but not engaged in routine handling of radium, do not show such blood changes. Case 4 at a later time showed an increase in lymphocytes.

DETERMINATION OF SENSORY THRESHOLD

Although the sensory changes in the affected fingers, as described above, were marked, it seemed desirable to check these up by a determination of the "sensory threshold" of the affected compared with the unaffected fingers. These determinations were kindly made by Mr. John P. Richards under the supervision and direction of Prof. E. G. Martin, who devised special electrodes for the finger tips for use with the Martin apparatus which has been previously described.[5] Dr. Martin reported that of the cases studied (Cases 1, 2, 3, 4 and 8), all except Patient 8, who was quite insensitive on all fingers, showed rather striking differences between the radiated and normal fingers, the former being much more insensitive. This relative insensitiveness to the faradic current might suggest injury to the nerve rather than to the terminal sensory end organs. It may, however, be due in some cases to increased resistance of the skin because of thickening of the horny layer.

With the idea of determining whether demonstrable histologic changes occurred in the chronically affected and relatively insensitive finger tips, Oct. 7, 1914, under aseptic precautions, without anesthesia, fragments of skin, including a portion of the corium, were excised with scissors from the tip of the right forefinger and little finger of Case 1; in the first instance there was very slight bleeding and little pain, while in the latter there was rather marked bleeding, soaking through a dressing, and considerable pain. The fragments were potted in Zenker's fluid. Both finger tips healed readily in a few days. Paraffin sections stained in eosin and methylene blue showed numerous nerves and terminal special sense organs. No marked difference was evident between the fragment from the control fingers by this technic, and specimens were not available for Weigert and Marchi methods.

AVOIDANCE OF INJURY

Various methods have been devised, particularly by Dr. W. T. Bovie, for avoiding these injurious local effects by the least possible contact of the fingers with the radium. Forceps or special vises are used for holding tubes and screwing in or out the tips and eyes; special

5. Martin, E. G.: Measurement of Induction Shock, New York, 1912.

applicators in the form of metal boxes have been constructed so that the active tubes may be added after the filtration and protection have been arranged, and the surface applicator is then slipped by forceps into a special rubber envelope and fastened with adhesive. This is particularly to avoid wrapping them up by hand in sheet rubber. Leaded gloves, fingers, etc., are clumsy and are not readily worn.

In placing active tubes in special applicators, it will probably not be possible to avoid all contact with radium, and as the effects are not apparent at once, as when handling very hot objects such as heated glass, but only after a period of days or even weeks, it will be difficult to train a worker to avoid contact with the active apparatus.

In the work of making routine applications of radium there should be a rotation in the staff, and persons affected should be freed at least temporarily from such work.

Fig. 8 (Case 6).—Superficial ulceration on thigh; a reaction from the accidental application of radium, due to keeping radium tube (32 millicuries) in trouser's pocket for an hour.

In order to avoid possible general disturbance, the body should be protected as far as possible by metal screens in form of boxes or plates about the radium; there should be frequent ventilation of work rooms, particularly if there is radium emanation present, and a change of duty, shorter hours and periodic physical examination of those working with radioactive substances with special reference to the blood examination is indicated.

SUMMARY AHD CONCLUSIONS

From the foregoing it is evident that marked changes may occur on the fingers of those engaged in routine work with radioactive substances. These local objective changes consist chiefly of flattening of the characteristic ridges, thickening and scaling of the superficial layers

of the skin and even atrophy and intractable ulceration. These lesions are usually slight compared with the marked subjective symptoms, such as paresthesia, anestheia of varying degree, tenderness, throbbing and even pain. The persistence of such effects is noteworthy.

Various general systemic symptoms and also blood changes may be produced by exposure to radioactive substances. To avoid such local and general disturbance, special protective and preventive measures have been devised, and those engaged in routine handling of radioactive substances are particularly cautioned.

A CONVENIENT FORCEPS FOR HANDLING RADIUM TUBES.

CHARLES H. VIOL, PH.D.

The writer has had occasion to handle radium tubes very frequently in the past three years. In this time about fourteen grams of radium element in the form of the different radium salts have been produced in the Radium Research Laboratory of the Standard Chemical Company and most of this radium has been supplied in tubes and applicators for radium therapy. At the outset little information was available as to methods for handling the material, and with a realization of the great value of the material being handled and with no exact idea of the dangers involved, it was the custom at first to handle the tubes with the bare hands. This was soon found to be disastrous, resulting in the production of typical radium burns on the ends of the thumbs and forefingers. The intensity of the radiations from the radium tubes falls off almost in accordance with that expected for a point source of radiation, namely, inversely as the square of the distance. Thus in a tube handled with the bare fingers, the radium is less than half a millimeter distant from the skin. The same tube, if five centimeters distant from the skin, is then one hundred times farther removed and the intensity of radiation is, in accordance with the above, approximately one ten-thousandth as great as where the radium is handled with bare fingers.

From this is seen the advantage of a forceps which enables one to handle the radium preparations safely and so prevent the necessity of having the radium approach very near to the hand. The necessity for precautions against radium burns is especially great for physicians and surgeons, since the radium burns cause a dulling or loss of the fine tactile sense in the parts affected.

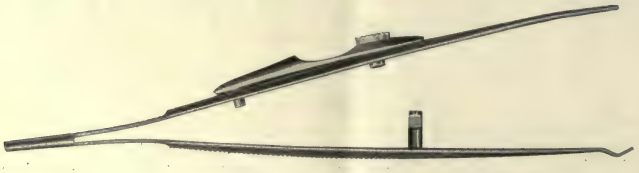

Figure 1.

By modifying the well known Novy's cover glass forceps the writer secured a forceps which for the past two and a half years has been most satisfactory for handling radium tubes of all sizes, and in this time there has been only one breakage of a radium tube due to the forceps. Over five hundred tubes have been prepared in the laboratory in the time mentioned, all of them being handled repeatedly, so that the breakage of one tube in the hands of an inexperienced assistant speaks well for the safety with which one may handle the tiny glass tubes of radium salt, with this forceps.

The forceps may be readily prepared from a Novy's cover glass forceps with lock—by the following method: First untemper the ends

Figure 2.

of the blade and the sharp pointed tip of the two arms of the forceps by heating to redness for a moment in a flame, allowing the forceps to cool slowly in the air. This untempering of the steel prevents the breaking of the forceps, which otherwise is likely to occur in bending the instrument. The curved pointed arm is next straightened by means of a small pair of pliers, and the end of the flat blade is bent into a shallow V as shown in Fig. 1, which represents the forceps in 8/9

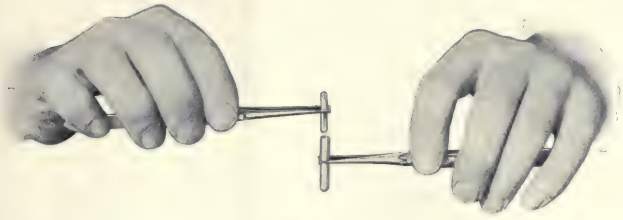

Figure 3.

natural size. The tension of the two arms of the forceps can be adjusted by bending, using a thick match stem or a thin lead pencil, until the adjustment is such that the match stem can be held in the forceps without slipping, when the lock is fully closed, Fig. 2. Fig 3 shows the method of placing the radium tube in the silver capsule, which is then closed by a screw cap. Figure 4 shows the silver capsule being placed into a brass screen of one millimeter wall thickness. By having a few such forceps at hand, radium can always be safely handled, and the risk of radium burns is greatly minimized.

Rubber gloves impregnated with lead, etc., such as are used for protection in X-ray work, are of little value when it comes to handling radium, since these gloves make it very awkward to manipulate the small tubes and screens, and the possibility of burns, because of the additional

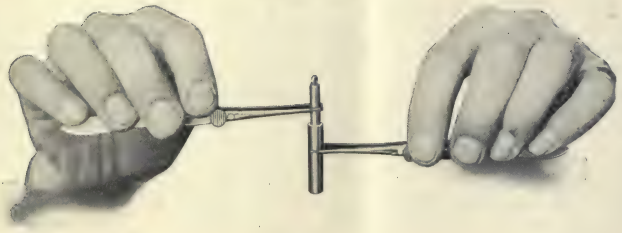

Figure 4

time necessary in the handling, probably more than compensates for the screening effect of the gloves. The writer has always abandoned the gloves after a short trial.

So far, in this laboratory, none of the workers have received radium burns of such severity as to require special treatment. In one case of malignant disease treated by very extensive applications of radium a favorable result was obtained as far as removal of the malignant growth was concerned, but a very severe radium burn was produced which caused intolerable pain. All methods were tried in an effort to give the patient relief and it was found that cocaine, etc., instead of relieving the pain appeared to make the condition worse. Partial relief was attained by frequent dressings with carbolated vaseline. Even greater relief was afforded by repeated dressings with aseptinol, a proprietary preparation apparently containing tar or cresols. A half per cent. solution of phenol was found to give relief in another case of a severe radium burn.

REVIEWS AND ABSTRACTS.

James F. Percy, M.D. (Galesburg, Ill.). The Value of Heat in the Treatment of Massive and Utterly Inoperable Uterine Carcinoma. The Pennsylvania Medical Journal, Vol. XIX, No. 4, January 1916, pp. 236-45. (Read before the Section on Surgery of the Medical Society of the State of Pennsylvania, Philadelphia Session, September 23, 1915). As regards radium therapy Dr. Percy said: "It may not be out of place, not only to emphasize the importance of using the heat technique in cancer of the uterus, as a preliminary to using the knife, when the surgeon decides that the knife is the wise procedure; but as much can be said for the heat treatment as a preliminary to the use of massive doses of the X-ray and radium."

"To attempt to treat a mass of cancer over three inches in diameter with either large doses of the X-ray or radium may give rise to dangers not very dissimilar to the use of the knife, to active manipulation of the growth, or to use of the curet, spoken of above. Neither the X-ray nor radium can safely be used to attack large masses of cancer with the hope of destroying it by one application of the treatment. When the X-ray or radium is applied to an exuberant overgrowth of cancer,

three spheres of influence are left as a probable result of the treatment: First, a destroyed area; second, an intermediate zone of more or less free and broken down cancer cells; third, an untreated region which in the beginning of the application of either the X-ray or radium must comprise the larger part of the growth. The first, or destroyed region, need not specially concern us in this paper, except possibly to question the chemical or physiological effects produced on the body cells generally by an overdose of this broken-down material, due to lack of drainage. On the other hand, I am convinced that if the dosage by absorption of this broken-down material could be regulated, it would have much to do with increasing the bodily resistance in overcoming the small points of metastasis already existing, or which would otherwise develop."

"The amount of disintegration and destruction of cancer cells produced by either radium or the X-ray in a mass of cancer will probably always remain an unknown factor. If this is to remain true, then the words just used, viz.: 'disintegration' and 'destruction' assume new importance in this connection. The disintegrated cells are available for absorption after the use of these agents, but neither the X-ray or radium provides for the escape from the body of the overdose of these dangerous to life cells. In other words, I repeat, there is no drainage."

"Another important consideration in the use of either the X-ray or radium, over which we have no control, is the determination of the amount of stimulation to renewed growth produced in cells only imperfectly reached by X-ray or radium applications in the larger masses of cancer. This comprises the intermediate zone already spoken of and, in a measure, the 'untreated region.' These two areas, of necessity, must more or less imperceptibly run into each other."

"In my early work with the application of heat, I was afraid to destroy the giant cancer masses, especially in the pelvis, for fear of doing more than the patient could tolerate in the way of an operation. I lost four patients, all of whom died with practically the same symptoms, before I determined the cause of the trouble. Postmortem examination disclosed more or less of these lytic cells in a pultaceous mass, free in the pelvis. In one case there was easily a pint of this material. From these experiences I learned of the significance and danger of these free cells. It might be well here to describe the characteristic symptoms that may develop from an over-absorption of this material, which the physiological chemists tell us contains so large a percentage of lysin. The patients who are the subjects of this fatal form of intoxication as a rule do perfectly well for four days. At the end of that time, they begin to show signs of exhaustion; the weakness becomes most profound. No local symptoms, which would help explain the condition, can be recognized. The heart increases in action and lessens in force. Mental oblivion begins to manifest itself, and vomiting, together with attacks of syncope, develop; the stupor increases and an acetonemia closes the scene. It was the experience gained in losing these four cases that changed by technic from a partial application of the heat at the first sitting to one where I coagulated all of the mass possible at one sitting. In addition to this, if the cavity left in the cancer mass after the application of the heat is not in a situation where good drainage can be maintained, I provide for it. I consider drainage so essentially a part of the destructive treatment of cancer that I wish to emphasize not only the danger of a lack of it, but, again, that the treatment of cancer today, by heat, provides the most efficient means

for drainage at out command. After the great emphasis I have placed on the question of cancer-cell absorption, it at once becomes necessary to remind you that this absorption does not take place in every case after the use of the X-ray, radium, or heat methods of destroying carcinoma; but that it is a potential danger the four deaths just mentioned, I think, amply show."

"That the X-rays and radium are valuable agents, after the gross mass of cancer has been destroyed by the application of heat, I am sure cannot be questioned. When I refer to the probable beneficial effects of the X-ray and of radium, I have in mind the use of these agents by those qualified to employ them. From what I have learned of the use of radium and of the X-ray, I am convinced that errors of omission and of commission, due often to the inexperience of the user, and, too, to inefficient X-ray apparatus, together with too small a quantity of radium, are responsible for many of the failures to benefically influence, in a destructive way, the progress of cancer by these agents."

Discussing the above paper Dr. John G. Clark (Philadelphia), said: "About three years ago there came across the water from Germany the reports of remarkable cures from the application of radium and mesothorium. At first these reports were received with incredulity, but with the increasing series of remarkable cures appearing in the literature from the representative clinics of Europe, we all felt that earnest heed must be given to these new suggestions. The record of results in the hands of Bumm, Kroenig, Schauta, Doederlein and even Wertheim are remarkable, and hopelessly inoperable cases have been cured after the application of radium so far as local manifestations are concerned. In our country, Drs. Kelly and Burnam have just reported an astounding series of over 150 cases before the San Francisco meeting of the American Medical Association, in which the results at present look as though they might excel after the five-year period the highest percentage of cures obtained through the most radical surgical efforts. In our own short experience with radium at the University Hospital, we have already had some startling cures of local conditions in hopelessly inoperable cases."

"This brings us back to just one fact, viz., that even in the presumably inoperable cases, the cancerous process often has not metastasized beyond the pelvic tissue and if a remedial agent can be found which will destroy the cancer cells within this area the patient will be cured. I take no issue with Dr. Percy but wish to commend his efforts in the most cordial way and to congratulate him upon his ingenuity. We are all earnestly seeking the best solution of this pathologic riddle of the ages. In this discussion, however, I cannot disregard Dr. Percy's theoretic objections to radium, for they do not hold good in our observation of cases treated by this means. My experience in the employment of radium and also that of almost every other observer do not show that there are more than evanescent toxic manifestations such as he fears from the destruction of the cancerous tissue. The excellent convalescence of these patients is the thing which commends this remedy."

"I consider the heat method as applied by Dr. Percy an extremely hazardous one in any but skilled hands. If there is any operation thus far devised which carries the greatest danger in unskilled hands, this one surely does. Such is not the case with radium. There must be a very high mortality percentage with his method; with radium, there is

practically none. With his method, there is a major operation, and a slow recovery. With radium, there is no operation and only a few hours detention in the hospital."

"My feeling, therefore, is that Dr. Percy must show by his statistics that by the application of the desiccating cautery he is excelling the radium method and time alone will settle this point. I am sure it would be of interest to all of us to know the mortality percentage attending the Percy method, the incidence of fistulas, and the actual cases thus treated in which the patients are alive after even one year. These questions are asked in no spirit of carping criticism, but to bring out the disadvantages as well as the successes incident to the employment of this method. We are all only too eager to grasp any suggestion which may improve our therapeutic efforts in the cure of cancer."

"Dr. Percy's brief in favor of the use of the cold cautery is quite logical and he may ultimately present a better series of cases of the more advanced cancers of the uterus after five years than with the most radical operation. In one aspect, I feel just as he does, that a radical operation after the thorough use of the cold cautery will be of questionable value. The same may be said of the class of cases which are locally healed by the use of radium. After either of these methods have been employed, I do not believe such an operation advisable, and I would be quite willing to take the risk of recurrence after the thorough use of the cautery followed by the local disappearance of the malignant process rather than to subject the patient to a radical operation later with its high attendant mortality. If the cautery in these advanced cases can not circumvent the growth, certainly the knife in the most skilled hands will not do so. While Dr. Percy expressed enthusiastic hope as to his results in apparently incurable cases, we, on the other hand, have had such satisfactory results from the use of radium that I feel it my duty to continue along this line, but I am free to say to every surgeon here, if you have no available radium, then adopt the Percy method in the advanced cases, for I believe it should be given a thorough trial. In the earlier cases, however, I still hold that in preference to either the Percy method or the application of radium, the thorough removal of all locally involved tissues is the more certain and effective procedure."

"In this position, we are sustained by collective statistics from many clinics, which have proved by the five-year period that at least thirty-three per cent. may be cured. With a wider interval of observation as to the merits of radium and of the Percy cold cautery are fully studied, we may find evidence so convincing that one or the other may supercede all other surgical methods. In none of Dr. Percy's papers thus far has he given us in detail the primary mortality incident to this radical procedure, the untoward results such as fistulas, intestinal complications, peritonitis, and many other serious sequellae that one may surmise will follow this treatment. In an otherwise hopeless class of cases, even if he can show only ten out of a hundred cured, he has made an advance. Such an advance, however, may be equaled or excelled by the use of radium if I mistake not the trend of events."

NOTES AND COMMENTS

In the table of the radioelements, given in Vol. 6, page 56, of this journal, a number of typographical errors were discovered in the figures giving the atomic weights of the radioelements; and for this reason a corrected copy of the table is reprinted herewith. As before, the half decay period of the element is given under the name of the element; the large Roman numerals indicate the maximum valence of the element; the ray emitted by the disintegrating atom is shown by the Greek letters, and the figure in the circle gives the atomic weight.